Improving forecast skill by assimilation of quality-controlled AIRS temperature retrievals under partially cloudy conditions

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Background

- AIRS has long been recognized as an important contributor in atmospheric data assimilation. However, thinning, quality control, and assimilating AIRS only under clear conditions has resulted in very little AIRS data being assimilated in operational systems.

- Susskind (2007) documents a new strategy that allows improvement of soundings in partly-cloudy conditions:
  - Improved radiative transfer algorithm
  - Improved quality control
  - An accurate AIRS-only cloud-clearing and retrieval system

- This particular experiment illustrates the importance of assimilating cloud-cleared AIRS data in the lower troposphere over the Arctic region for improving forecasting skill in the northern hemisphere extra-tropics.

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Experiment

- We generated three GEOS-5 assimilation runs:

  - Control assimilation (CNTRL) is the GEOS-5 DAS Version beta7P2 at 1x1 degree resolution, run 12/17/02 through 1/31/03 – contains conventional and satellite data, but no AIRS retrievals.

  - "AIRS" assimilation is the 1x1-deg. GEOS-5 DAS Version beta7P2 with same data as control plus AIRS version 5 retrievals with "medium" quality control and SRT-generated error estimates added as rawinsonde temperature profiles. It was run from 1/1/03 through 1/31/03.

  - "CUTF" assimilation is the 1x1-deg. GEOS-5 DAS Version beta7P2 with same data as control plus AIRS version 5 retrievals with "medium" quality control added as rawinsonde temperature profiles only above the 200mb level. It too was run from 1/1/03 through 1/31/03.

Experiment – cont.

- We ran three sets of 27 5-day forecasts, initialized at 00Z each day, from 1/5/03 through 1/31/03:

    - "CNTRL" set initialized from the control assimilation
    - "AIRS" set initialized from the AIRS assimilation
    - "CUTF" set initialized from the CUTF assimilation

    - We skipped first 4 days to allow for spin-up of the AIRS assimilations.

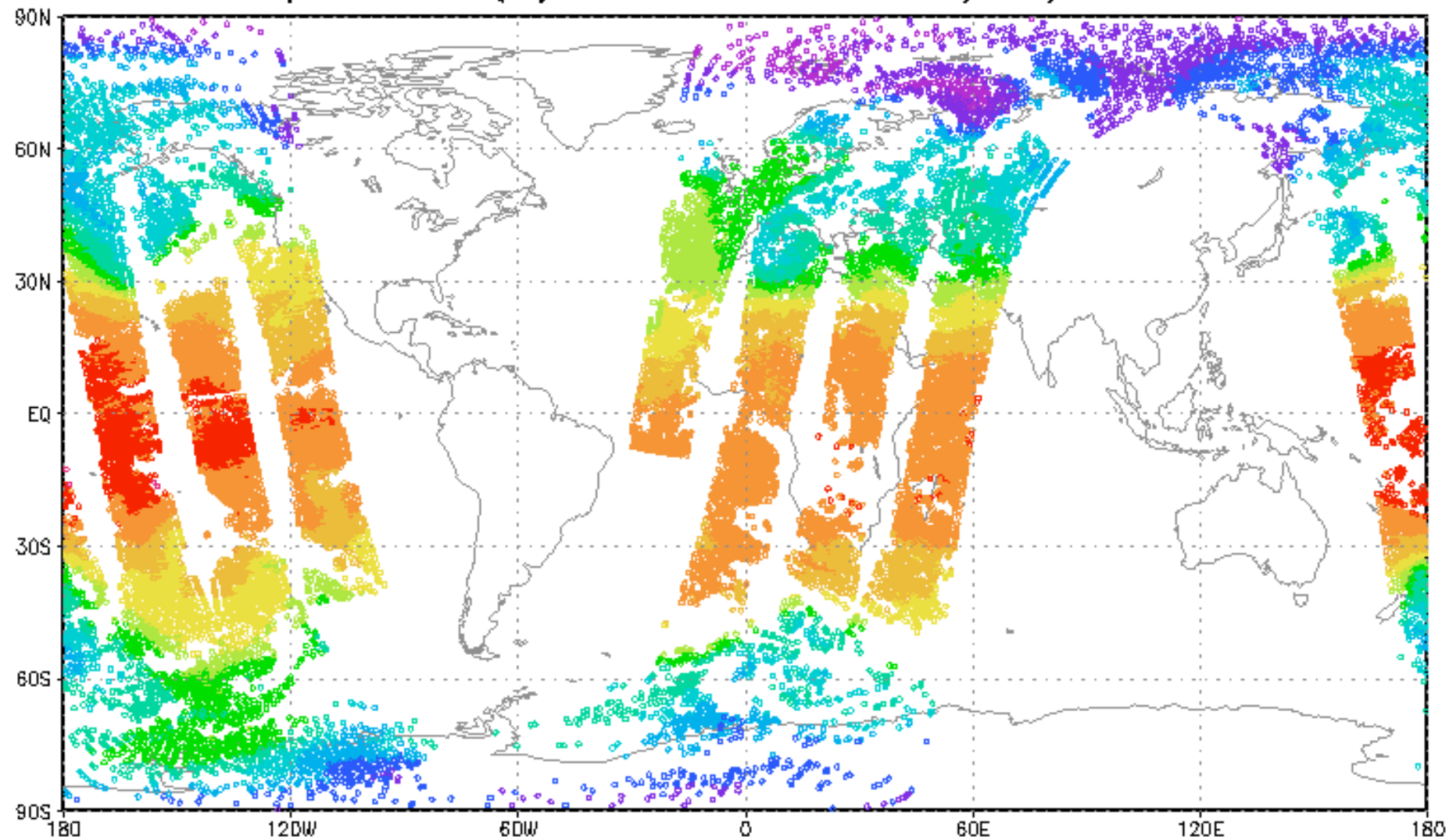- We verified all three sets against the NCEP analysis
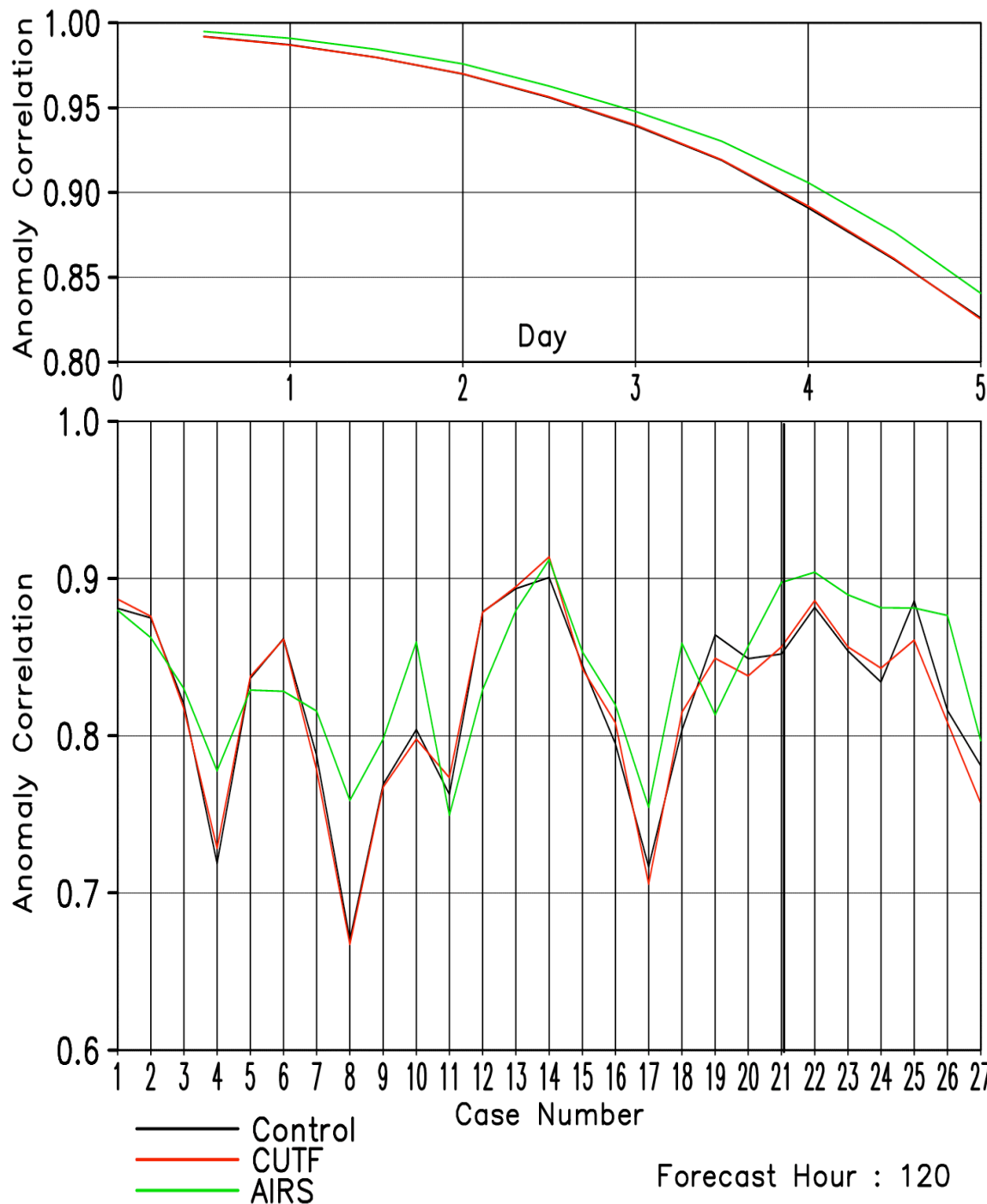
RESULTS:

Top panel shows the 500mb geopotential height anomaly correlation in the Northern hemisphere extra-tropics of the average of all 27 forecasts against NCEP analysis as a function of forecast period.
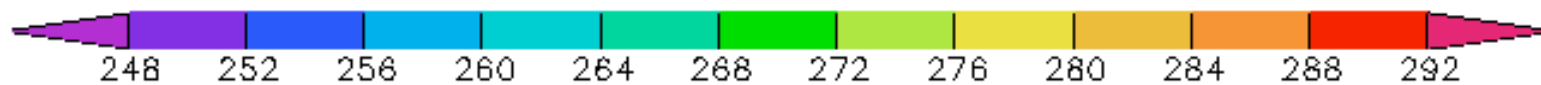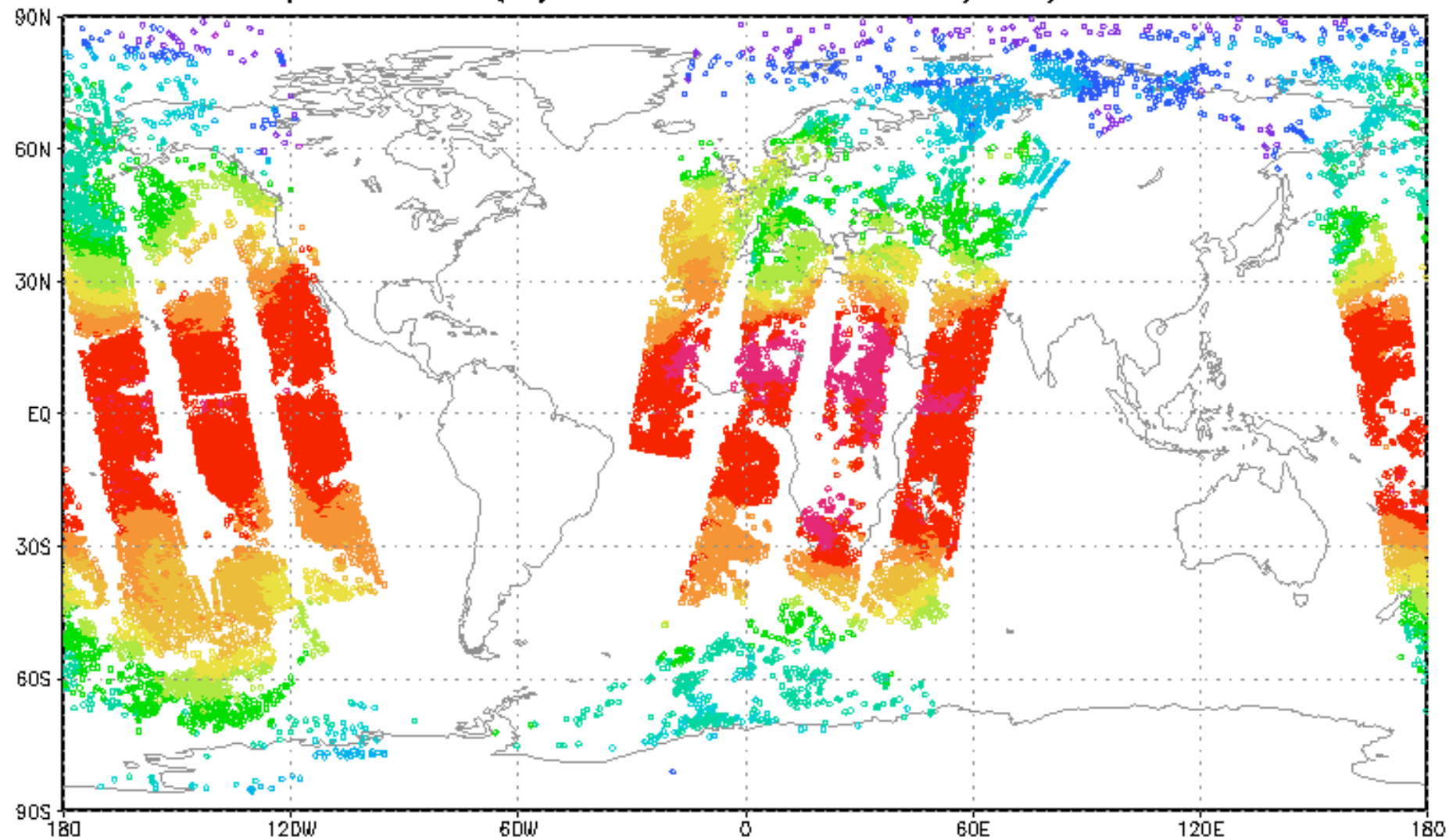
Bottom panel is the day-5 500mb geopotential height anomaly correlation for each of the 27 forecasts

AIRS forecasts demonstrated superior skill over both the CNTRL and CUTF in most of the cases. We examine more closely Case 21 (init. 25 Jan) in which the CNTRL and CUTF produced good skill but the AIRS forecast showed significant improvement
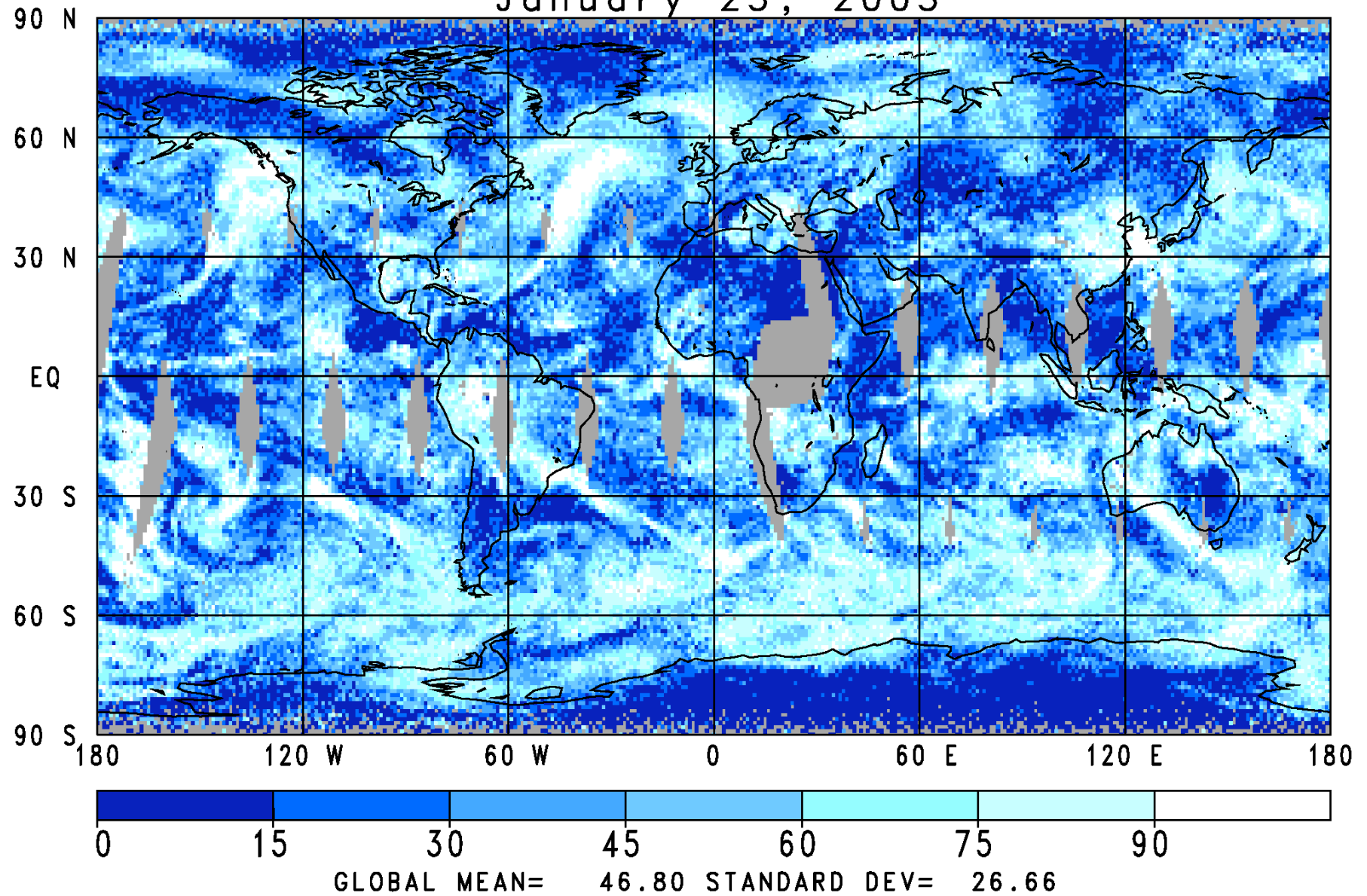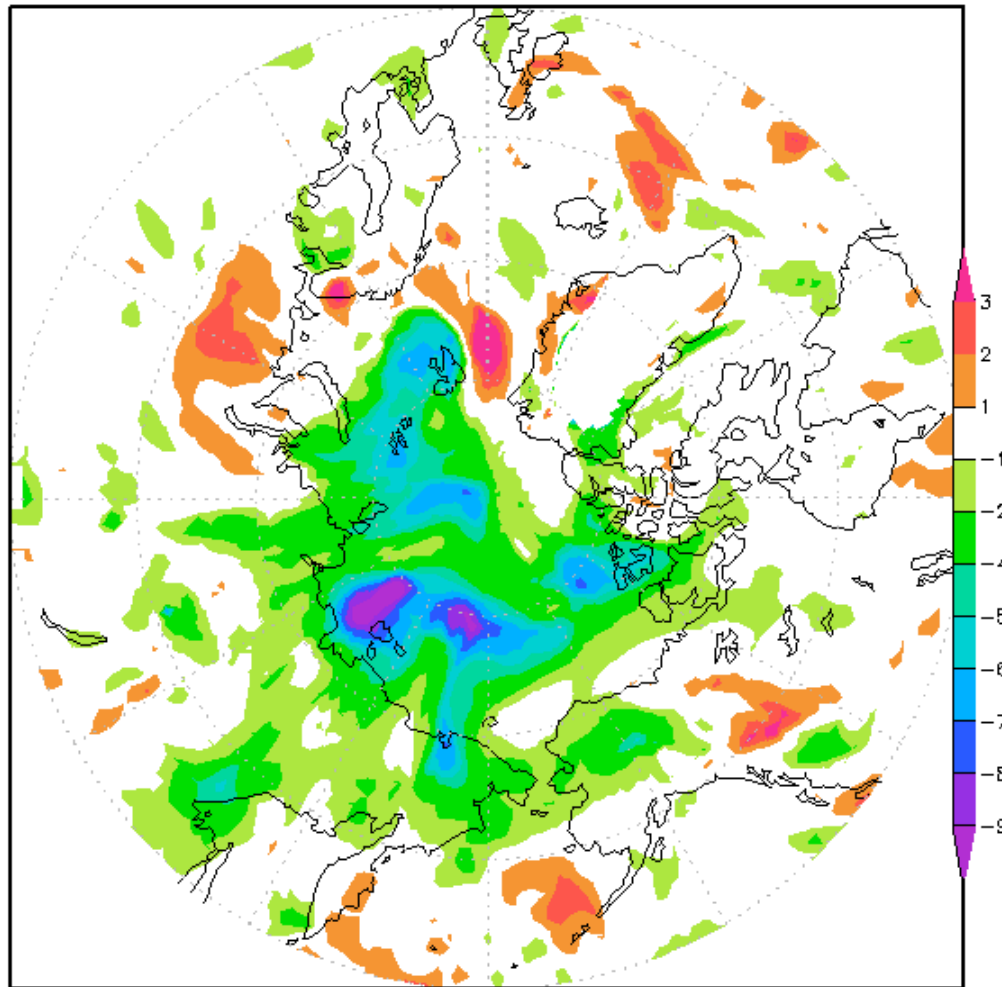
Temperature (K) v501m 506hPa 1/25/2003 00Z

231.8 235.6 239.4 243.2 247 250.8 254.6 258.4 262.2 266 269.8 273.6

GrADS: COLA/IGES

2007-08-16-18:25

Temperature (K) v501m 840hPa 1/25/2003 00Z

248   252   256   260   264   268   272   276   280   284   288   292

GrADS: COLA/IGES

2007-08-16-18:32

AIRS Effective Cloud Fraction
January 25, 2003

GLOBAL MEAN=   46.80 STANDARD DEV=   26.66
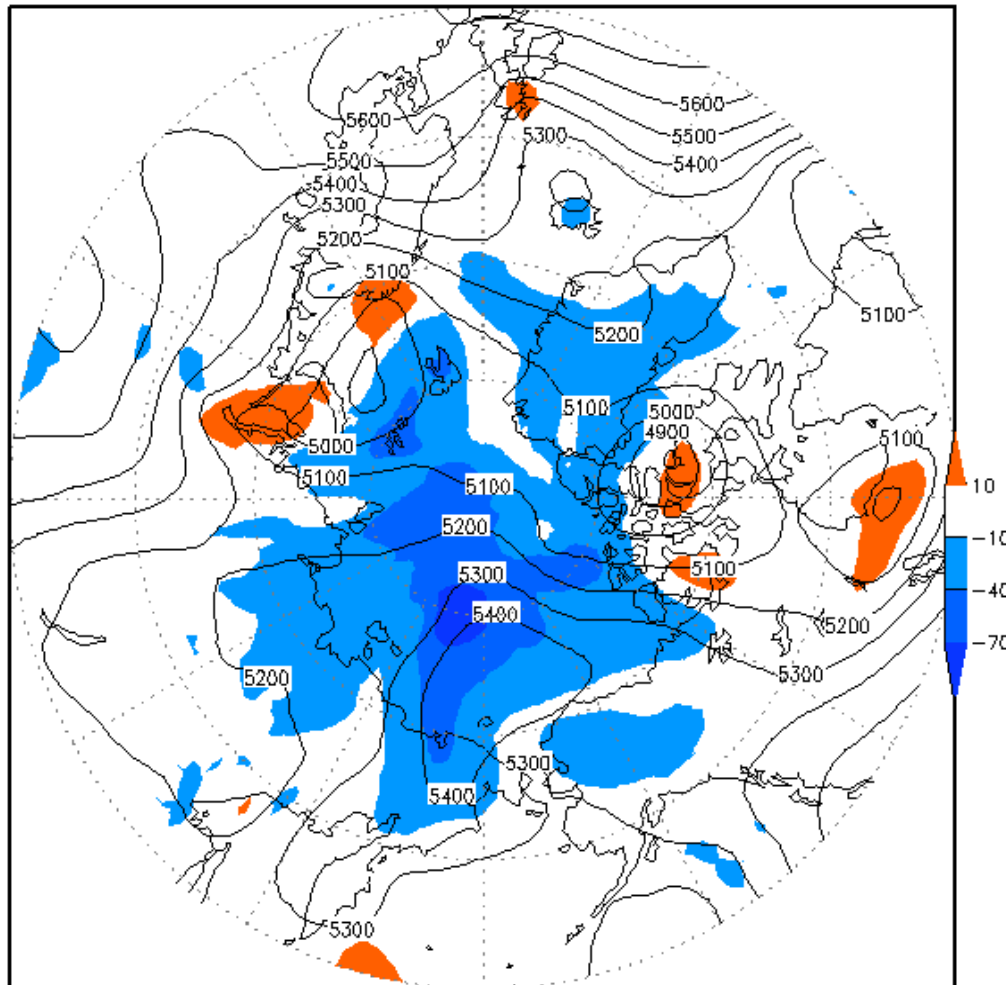
800hPa Temp AIRS minus CNTRL

This panel shows 800mb temperature anomaly (AIRS minus CNTRL) at the initial forecast time (00Z 25 Jan). Notice the large area of negative anomaly over northeastern Siberia, Alaska and the Arctic region.
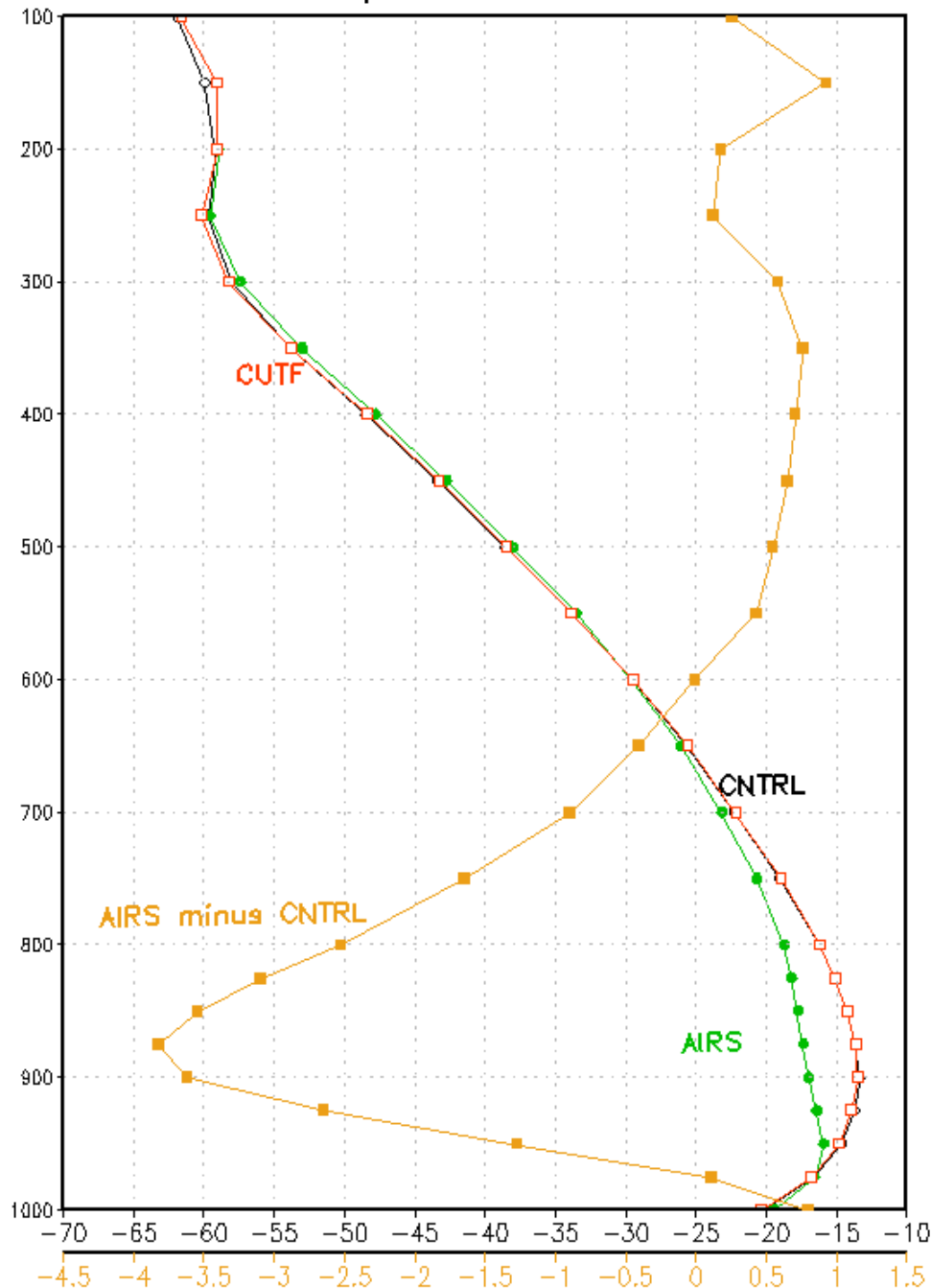
500hPa Geop AIRS minus CNTRL

This panel shows the 500mb geopotential height anomaly (AIRS minus CNTRL) at the same initial forecast time (00Z 25 Jan).

The geopotential height hydrostatic adjustment due to lower temperatures causes the 500mb geopotential in the AIRS case to be much lower than the corresponding CNTRL analyses.

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Temperature Profiles

CUTF

CNTRL

AIRS minus CNTRL

AIRS

This chart shows temperature profiles, averaged over the entire Arctic region (70-90N) from 1000 to 100mb at the initial forecast time (00Z 25 Jan) of the three forecasts:
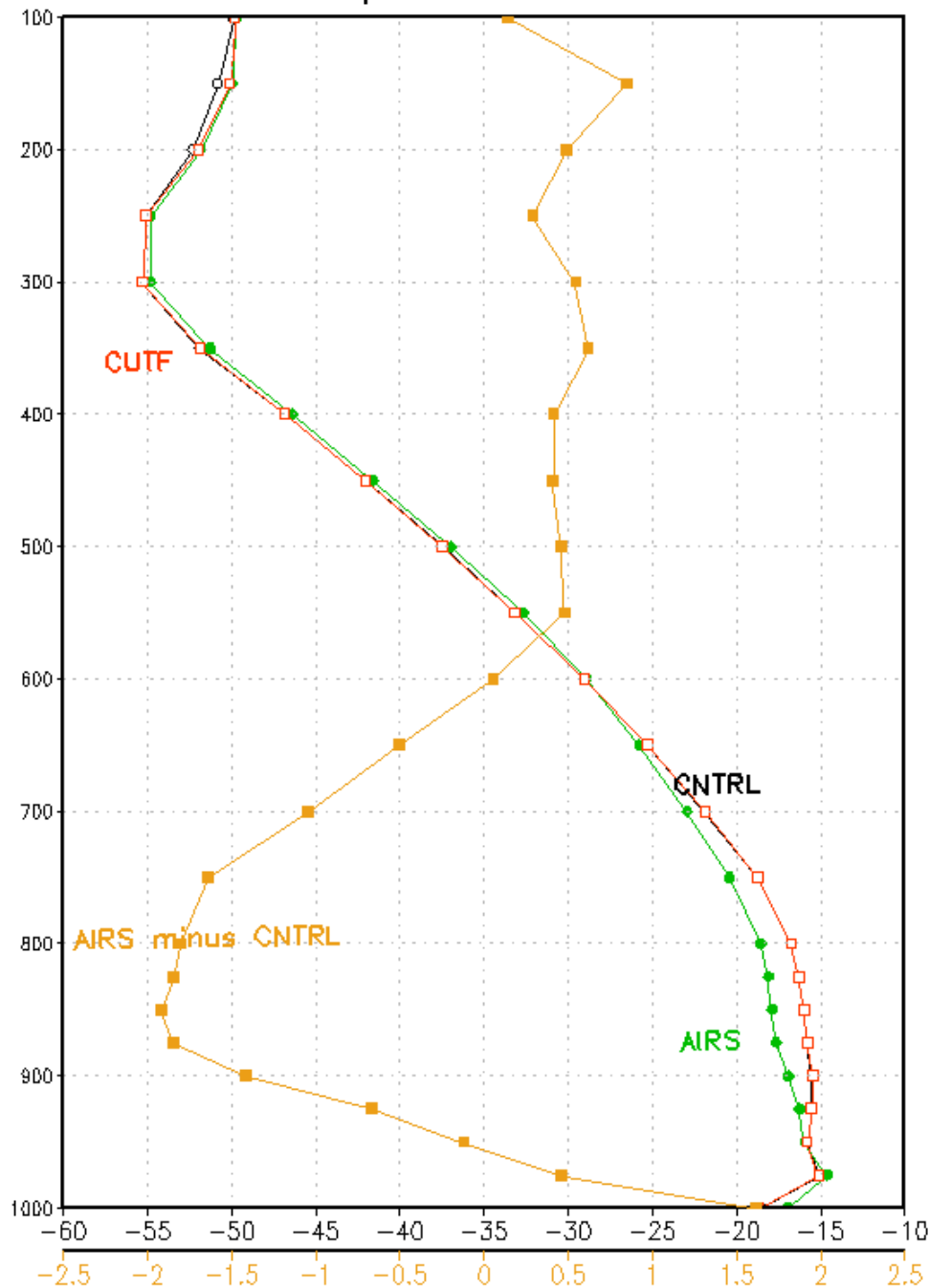
CNTRL = black
AIRS = green
CUTF = red

and the AIRS minus CNTRL temperature difference profile (orange).

The inclusion of AIRS data in the lower-mid troposphere results in significantly colder temperatures between 950 and 700mb, with a peak at about 875mb.

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This chart shows temperature profiles, area-averaged over a more limited region (100E-170W, 50-90N) over northeastern Siberia up to the Pole, from 1000 to 100mb at the initial forecast time (00Z 25 Jan) of the three forecasts:

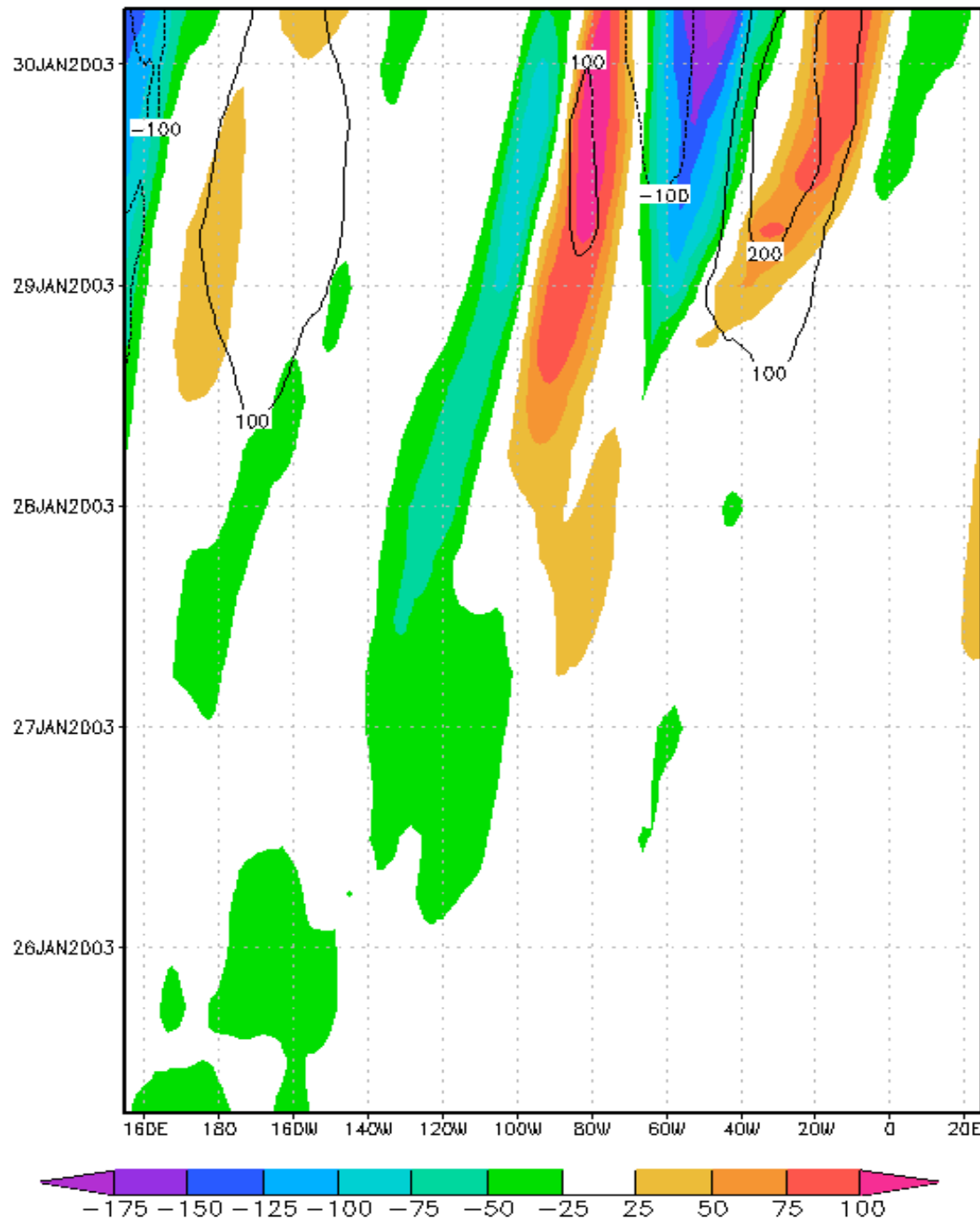CNTRL = black
AIRS = green
CUTF = red

and the AIRS minus CNTRL temperature difference profile (orange).

Again, over this region, there is a significant negative temperature anomaly in the AIRS assimilation.

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500hPa AIRS minus Control Latavgd 40-80N

This Hovmoller diagram shows the latitudinally averaged (40-80N) 500mb geopotential height anomaly (AIRS minus CNTRL, shaded, and NCEP minus CNTRL, solid) as a function of forecast time.

Notice that the initial negative anomaly, appearing as a wave packet, over Siberia and Alaska, undergoing dispersion, amplifying and propagating eastward . The AIRS-CNTRL anomaly observed at day 5 over Canada and the north Atlantic corresponds well with the NCEP-CNTRL in the same region.

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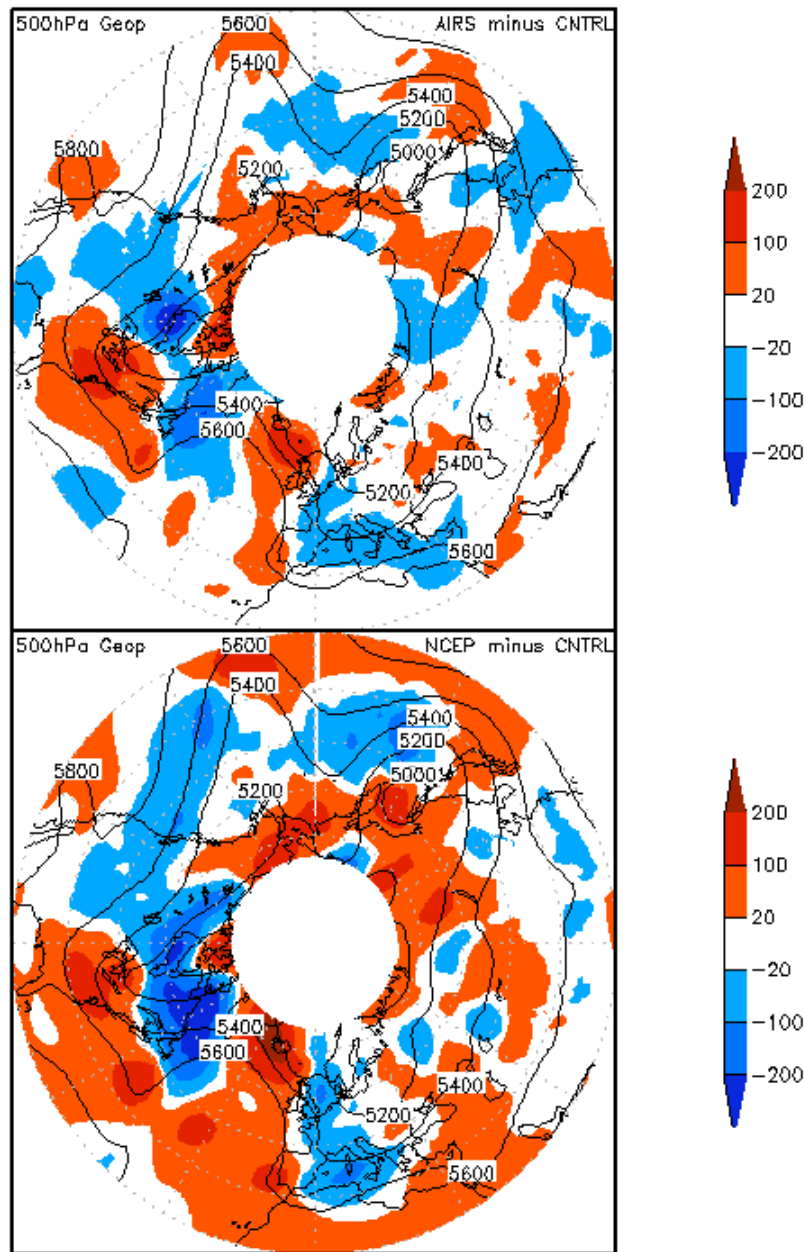
This shows the 500mb height anomalies at day 5 of the Jan 25 forecasts (verified 00Z 30 Jan).

Top panel is AIRS minus CNTRL (shaded) and CNTRL (solid)

Bottom panel is NCEP analysis at 00Z 30 Jan. minus CNTRL forecast at day-5 (shaded) and the day-5 CNTRL forecast (solid)

Again, there is a good correspondence between AIRS-CNTRL and NCEP-CNTRL over North America and the north Atlantic

Summary

- The inclusion of low-mid tropospheric AIRS retrieved temperature profiles in the GEOS-5 assimilation were essential to improving the average skill of 27 5-day 500mb geopotential height forecasts in NHXT in January 2003.

- A case study illustrated how a better representation of the low-mid tropospheric temperature structure by the AIRS assimilation over the Arctic region led to an improved 5-day 500mb geopotential height forecast over a large area of the NHXT.

- Since the Arctic and Antarctic regions lack both conventional and geostationary satellite observations, they can benefit greatly from high-quality polar orbiter data.

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Future Work

- Running assimilations using the current GEOS-5 DAS at half-degree resolution

- Assimilate new AIRS version 6 retrievals when available

- Assimilate both retrievals and cloud-cleared radiances.

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Special Thanks

- Michele Rienecker and the GMAO for providing the GEOS-5 DAS and the technical support needed to set up and run these experiments.

- AIRS team at JPL and the Sounder Research Team at NASA Goddard for providing the retrievals used in this experiment.